AD________________

Award Number: DAMD17-01-1-0267

TITLE: A Partnership Training Program in Breast Cancer Diagnosis: Concept Development of the Next Generation Diagnostic Breast Imaging Using Digital Image Library and Networking Techniques

PRINCIPAL INVESTIGATOR: Mohamed F. Chouikha, Ph.D.

CONTRACTING ORGANIZATION: Howard University
Washington, DC 20060

REPORT DATE: October 2004

TYPE OF REPORT: Annual

PREPARED FOR: U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 074-0188

1. AGENCY USE ONLY (Leave blank)	2. REPORT DATE	3. REPORT TYPE AND DATES COVERED
	October 2004	Annual (4 Sep 2003 - 3 Sep 2004)

4. TITLE AND SUBTITLE
A Partnership Training Program in Breast Cancer Diagnosis: Concept Development of the Next Generation Diagnostic Breast Imaging Using Digital Image Library and Networking Techniques

5. FUNDING NUMBERS
DAMD17-01-1-0267

6. AUTHOR(S)
Mohamed F. Chouikha, Ph.D.

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Howard University
Washington, DC 20060

E-Mail: cm@scs.howard.edu

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Medical Research and Materiel Command
Fort Detrick, Maryland 21702-5012

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for Public Release; Distribution Unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT (Maximum 200 Words)

This program represents a training partnership between Howard University (HU) (Department of Electrical Engineering, Department of Systems and Computer Sciences, and Department of Radiology); and Georgetown University (Image Science and Information Systems, ISIS). In this partnership training program, we will train faculty and students in breast cancer imaging, digital image database library techniques and network communication strategy. Experts from Georgetown and Howard University will participate in training through seminars, specialized tutorials and workshops. Outside distinguished speakers will also be invited to give talks in the lecture series. They will provide the faculty investigators and students with opportunities to discuss and to broaden the knowledge in breast cancer, imaging, database library and networking.

Our first goal is to provide the investigators at Howard with basic and updated breast imaging techniques as well as background knowledge in breast cancer diagnosis. We will develop a large digital image database. The database will be accessible through the web to support research and patient care. The optimal goal of this program is to equip HU investigators to acquire sufficient knowledge and tools in breast cancer and breast imaging that can lead them to conduct cutting edge research in the field. The program objectives are:

1. Offering breast image and breast cancer related lectures and seminars
2. Preparation of training materials including breast images and case reports
3. Concept development in breast imaging research
4. Development of competitive research grants.

14. SUBJECT TERMS
Partnership training program, breast imaging, mammography, digital image library techniques, networking techniques, computer-based diagnostic support system

15. NUMBER OF PAGES
19

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

Table of Contents

Cover..

SF 298..

Table of Contents...

Abstract...

Introduction...1

Body...2

Key Research Accomplishments...10

Reportable Outcomes..10

References...

Appendices...12

Abstract

This on-going training program consists of three components, namely: start up, training and research development stages. In the third year of this program, our main effort has been in providing faculties and students with additional lectures in breast imaging, coordination and digitization of mammograms aiming to establish an Africa-American women mammogram database, simulation of 3D breast modeling, and functional development for the use of mammogram database with networking techniques.

Under this partnership arrangement, we continued to make progress as planned. One Master student finished her thesis under this program. Six students received IRB training and passed NIH examination. Ten students received training and worked (and are working) on specific training research topics, and 260 mammography cases have been digitized. Progresses toward the database project are under way. Finally a mini-workshop was held to review grant application and to prepare for next year grant submission to NIH and other agencies.

1. Introduction

This program is a collaboration between participants from Howard University in the Department of Electrical Engineering, the Department of Systems and Computer Sciences, the Department of Radiology and the Cancer Center; and collaborating investigators from Georgetown University Image Science and Information Systems (ISIS). This on-going training program consists of three components, namely: start up, training and research development stages. During the start up stage, the faculty members are being trained in breast cancer imaging. The faculty members learnt how to develop a mammogram database and are in the late stage of developing a database for African-American women that will be available to Howard University and to the investigators involved in breast cancer research and in training the community at large. They also participated in a workshop aimed at developing expertise in writing successful proposals to federal agencies.

Georgetown University investigators and clinical members of the Howard University Hospital continued to offer a series of lectures including: Breast Anatomy, Physics and Instrumentation of Mammography, Breast Ultrasound, Breast MRI, State-of-the-Art Ultrasound Instrumentation, Cancer Biology and Physiology, Breast Cancer Oncology and Management.

Under this partnership arrangement, one Master student finished her thesis under this program. Six students received IRB training and passed NIH examination. Ten students received training and worked (and are working) on specific training research topics, and 260 mammography cases have been digitized. Progresses toward the database project are under way. Finally a mini-workshop was held to review grant application and to prepare for next year grant submission to NIH and other agencies.

2. Training and Research Activities

2.1. Lecture Series (Total 6 lectures and 1 workshop were provided to the faculty members and students at Howard University)

A. Program plan and Mammography Physics and Image Requirements (part 1)
– By Dr. S-C. Ben Lo (January 20, 2004)

1. Introduction of Howard BCRP training program
2. Introduction of X-ray physics
3. General X-ray imaging techniques

B. Program plan and Mammography Physics and Image Requirements (part 2)
– By Dr. S-C. Ben Lo (February 3, 2004)

4. Mammography physics
5. Screen/film processing
6. Film optical density as functions of exposure, film speed, processing temperature etc.

C. Nuclear Magnetic Resonance Image - By Dr. Paul C. Wang (February 17, 2004)

1. Explanation of the NMR imaging and spectroscopy diagnostic techniques
2. Illustration of the effects of NMR parameters of the samples such as T1 and T2 relaxation times, spin density and mobility, as well as the imaging parameters
3. Discussion about the potential uses of these techniques and the current research of this fascinating field.

D. Genetic Bases of Cancer - By Dr. Theodore Bremner (March 2, 2004)

1. Types of cancer: blood, connective tissue, epithelia tissue
2. Cancer-causing agents (carcinogens)
3. The control of gene expression
4. Proliferation
5. Survival

E. Mammographic Microcalcifications: - By Dr. S-C. Ben Lo (March 23, 2004)

1. Image patterns of microcalcifications and clustered microcalcification on mammograms
2. Morphology of benign and malignancy lesions
3. Technical methods for detection of clustered microcalicications

F. Detection and Classification of Breast Cancer- By Dr. S-C. Ben Lo (April 16, 2004)

1. Image patterns of breast masses on mammograms
2. Technical methods for the detection of masses
3. Demonstration of mammographic sample cases

G. Grant applications and review (May 21, 2004)

A mini-workshop (lasted 3 hours) – By Dr. S-C. Ben Lo, Dr. Chouikha and Dr. Jianchao Zeng

1. Introduction on health research (By Dr. Chouikha and Dr. S-C. Ben Lo) -20 minutes.
2. A video show regarding NIH grant review procedure (provided by NIH) -60 minutes
3. Break - 10 minutes.
4. Summary of the grant proposal review (By Ben Lo) - 40 minutes

5. Q&A session: Jianchao, and Ben will sever as panel members to discuss and answer questions on grant proposal review and related questions. - 60 minutes.

2.2. Activities for the Development of Future Bio-medical Engineering Training Program

Since Spring 2003, Howard University's Department of Electrical and Computer Engineering has worked with the other three University members in Washington DC to form the Washington Academy of Biomedical Engineering (WABME). The aim of WAMBE is to promote research, technology transfer, and education in biomedical engineering in the nation's capital region. The Academy is a framework where different institutions, each with unique resources and strengths, can explore and develop interdisciplinary research projects. This collaborative endeavor strengthens existing biomedical engineering programs and creates new scientific pathways for future discovery. The WABME website is http://www.wabme.org/

On March 2004, 5 members of this training program (Drs. Chouikha, Zeng, Kinnard, Lo, Freedman) visited NIH/NIBIB Training and Career Development Division, and met with the Program (Division) Director, Dr. Meredith Temple-O'Connor and 3 staff members. Part of the discussion was focused on the white paper sent by HU/GU team. Following the discussion, it was recommended that Howard and Georgetown prepare a proposal for NIBIB to develop a biomedical training program.

2.3. Multi-Component Image Feature Analysis of Breast Imaging

Project Advisors: M. Chouikha, Ph.D., S-C. Ben Lo, Ph.D. Student: Mona Y. Elshinawy

We are studying the All Channel Algorithm (ACA) technique. It is one of the amplitude and frequency modulations (AM-FM) modeling techniques that represent images in terms of instantaneous amplitude and frequency analysis. We intended to extract image patterns that represent mass features which can also be reconstructed as compared to the original image.

The Channel filter with center frequency Ω is described as follows:

$$g(x,y) = \left(\frac{1}{2\pi\sigma_x\sigma_y}\right)\exp\left(-\frac{1}{2}\left(\frac{x^2}{\sigma_x^2}+\frac{y^2}{\sigma_y^2}\right)\right)\exp(2\pi jfx) \tag{2}$$

where σ_x and σ_y are the standard deviations in the x and y directions respectively, f is the radial center frequency.

In the frequency domain the filter is the Gaussian

$$G(u,v) = 2\sigma_m\sqrt{2\pi}\exp\left\{-4\pi^2\sigma_m^2\left[(u-u_m)^2+(v-v_m)^2\right]\right\} \tag{3}$$

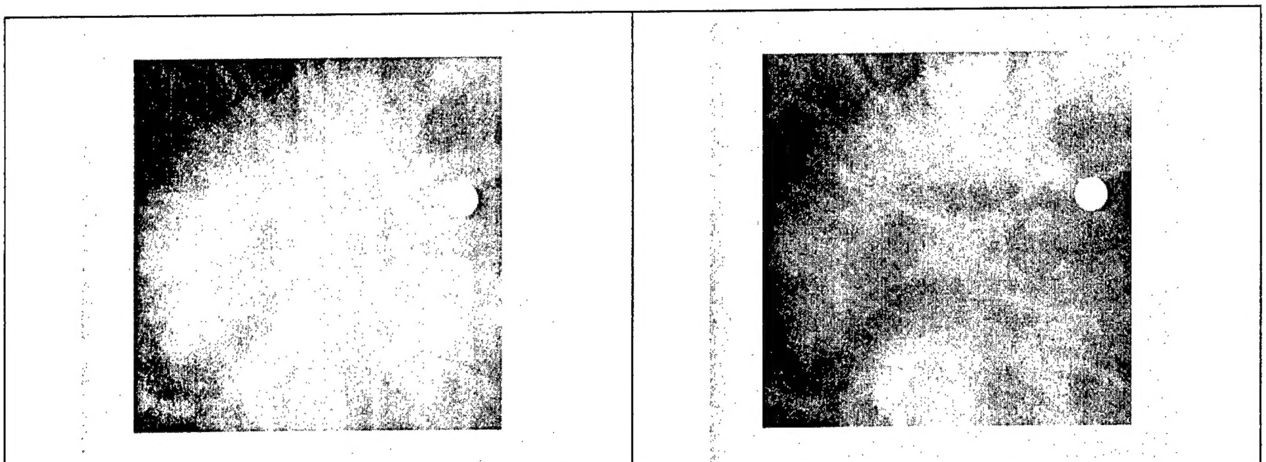
where σ_m is the standard deviation of the filter, and u_m and v_m are the Cartesian coordinates of the center frequency in the u-v plane respectively.

In this study, the following design was used: 40 filters arranged in eight rays, along each ray five filters are arranged with radial center frequencies starting with r_0=0.0375 Hz/pixel and progressing geometrically by with a common ratio R=1.8. The filter bandwidth used is B_{oct}=1 octave and η=1/2. The orientation bandwidth is computed as Θ=38.9424°. The angular spacing between rays is Φ=20.6418°. The starting angle value starts from –79.649° to 64.787°. Different standard deviations σ were used for each radial center frequency. These banks of filters were applied to mammograms and the resulted outcome wasn't satisfactory. The filtered images were distorted and no features were shown

Experiments

Many experiments were performed by changing the free parameters of the filter bank design. Good results were obtained when the initial radial center frequency was changed to r_0=0.07Hz/pixel. The parameters adjustment was done on the radial center frequencies.

A reconstructed image was compared with the original image to verify that this stage was behaving properly in this particular application. The average error percentage between the original and reconstructed images for the 50 test cases that were used in this study was 5.83%. There were reconstructed mammograms with errors as small as 2.45%, and others with errors as large as 9%. Figure 1 shows one example of a cancer case-malignant. The original Image is on the left side while the reconstructed image on the right side. The RMSE in this case was 3.86%, while the improvement of the image when the output of the 40 filters was added to the reconstructed image was 37.1%.



(a) The original mammogram	(b) The reconstructed mammogram

Figure 1: Display of both the original and reconstructed Mammograms of one of the cancer cases

Needle Diagram of AM-FM Modeling Technique

We also used the gradient of the image to describe the frequency and orientation of its components. Each arrowhead points in the direction Θ, where Θ is the orientation of the instantaneous frequency. The length of each arrow is inversely proportional to the amplitude of the instantaneous frequency. With this display convention, long arrows correspond to high instantaneous frequencies and image features of large spatial extent, while short arrows correspond to low spatial frequencies and image features of small spatial extent.

The importance of the needle diagram is in extracting more features of the filtered images of the bank of log Gabor filters. Instead of using the real images, the needle diagram can be used to describe the features of the masses in mammograms. It will be easier to detect the orientation of the frequencies from this diagram as well as the frequencies itself from observing the length of the arrows. Figure 2 shows three samples of the filtered mammograms with their corresponding needle diagrams.

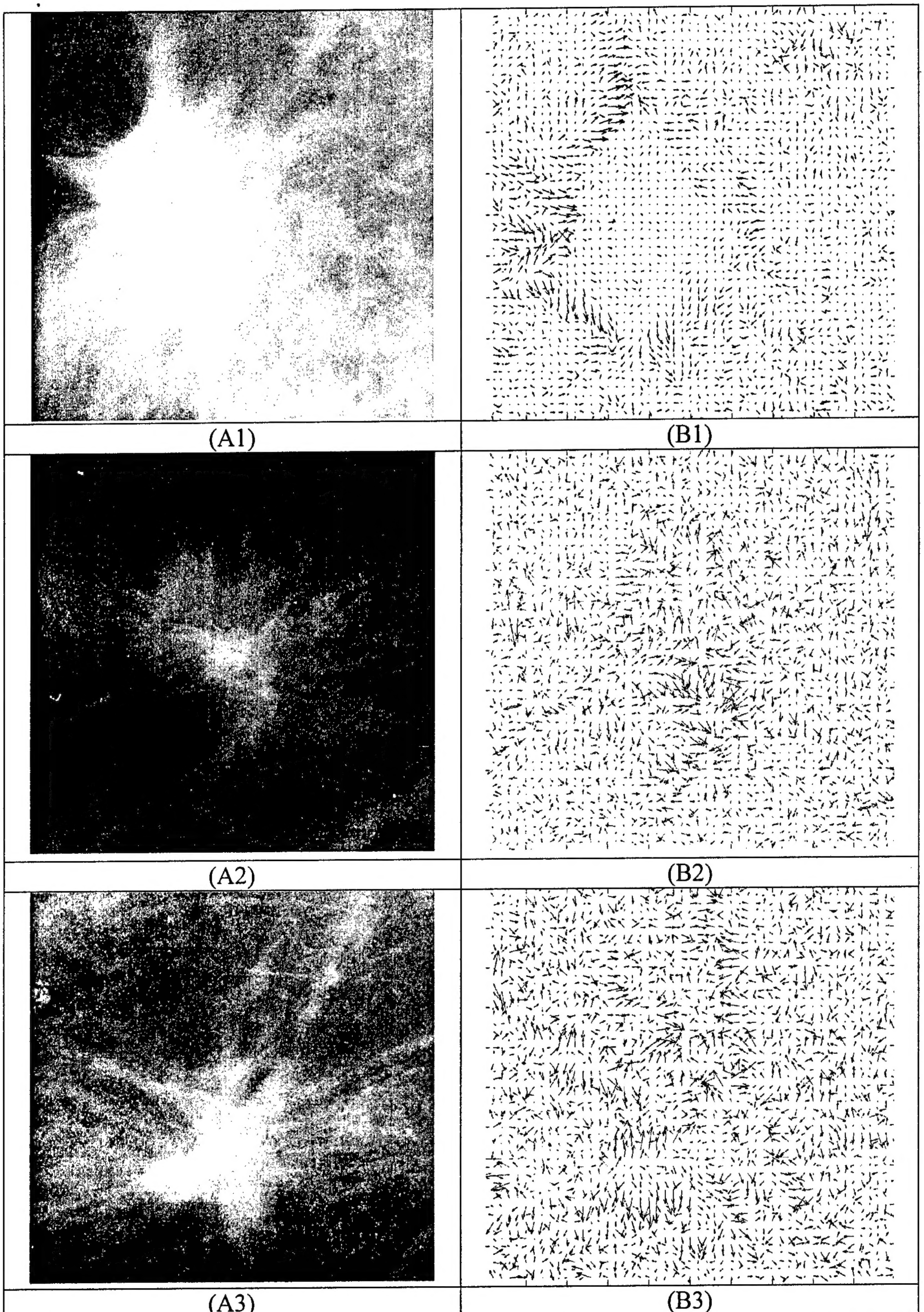


Figure 2. (A) The composite filtered image. (B) The corresponding needle diagram showing the gradient pattern of mass speculation

2.4. Digitization of film-based mammograms and Begin to Establish A Mammogram Database Featuring African American Women

Project Leaders: Ahmed Jendubi, Ph.D., Paul Wang, Ph.D.

Members and their qualifications: Several students have participated in this group of students, six undergraduates (Ms. S. Ross, Ms. O Ejeofodomi, Mr. O. Juma, Mr. L. Debo, Mr. Monyenye). Two undergraduate students have graduated (Ms. Ross E. Shani, B.Sc. in EE May 2004, Summa Cum Laude, now a graduate student in Bioengineering at the University Of Michigan, Ann Harbor; and Ms. O'tega Ejofodomi, B.Sc. in EE May 2004, Magna Cum Laude, now a graduate student in Electrical and Material Sciences at the EE dept. of Howard University). All students have taken and passed the Human Participants Protection Education for Research Teams online course, sponsored by the National Institutes of Health (NIH).

This team has focused on the following:

1. Train students on the use of the high-resolution (50micrometer) Mammography films.
2. Digitize and burn into CDs African American Mammography Cancer cases.
3. Start the development of a digital Mammography Viewer software (D-viewer) using Microsoft C-Sharp Language.
4. Start studying and understanding our mammography digital images to highlight possible suspicious cancer region area in a given mammogram.

Accomplishments

1. So far we have digitized two hundred sixty (260) cancer patient cases. Our cases range from a set of four Mammograms to as many as ten Mammograms, according to the patient status and yearly check ups.
2. For each patient (i.e. for each case), we have gathered all information as listed by the radiologist and tabulated it for inclusion in the Mammography Database (Apache-Mysql-PHP based) as developed last year by BC Mammography Database Team.
   Our emphasis has been to strive to scan to the highest possible resolution (50micrometer) Mammography films, document any notes from the Radiologist and save these information into tables that will go along with each digital Mammogram.
3. A preliminary Software package, called **D-viewer**, has been developed by our group in C-Sharp Language. So far we have coded the main menus and items that could be applied to a digital image, such as zoom, high/low pass filter, annotate part of the image with text and circle/rectangle. Our goal in this D-viewer Software package is to load a patient case (a set of DICOM Images) and find suspicious areas (such as mass or calcification) and draw a rectangle around them, with a goal of helping train Engineering/Science Students to spot possible anomalies in a mammogram. Ultimately, we hope that this software will help train Radiology undergraduate and Graduate students, and ideally help a Radiologist with a second opinion on where to focus attention in a mammogram.
4. To learn more about abnormal areas in a Mammogram, we are studying work done by the University of South Florida Mammography Database, and the MIAS database, where region of interest (mass or calcification) is highlighted by a group of radiologists.

Summary of D-viewer Software

An investigation is made to create an application that would display a digitized mammogram and manipulate it so as to enhance the image properties; this would undoubtedly help the radiologist.

PROBLEM STATEMENT

To create an imaging software application namely the 'DICOM Viewer' (*D-Viewer*) that is DICOM (Digital Imaging and Communications in Medicine) compliant and also offers image manipulation & enhancement. The '*D-Viewer*' would consequently aid the work of a radiologist in viewing medical images. The application should be developed using C-Sharp(C#) programming as wells as being 'Graphics Device Interface' (GDI) based.

THE 'D-VIEWER'

The '*D-Viewer*' will be able to perform numerous image manipulating functions to aid the viewing of mammograms. At the moment, the '*D-Viewer*' has only been developed to accept image formats that include Windows bitmap (.bmp), Joint Photographic Experts Group (jpg), Tagged Image File Format (tif), Graphics Interchange Format (gif) and Portable Network Graphics (png).

To make use of the '*D-Viewer*', the user loads the application by double clicking the icon, and the screen comes up. An image can then be loaded at this point with the appropriate format, and it is displayed on the user interface. There are numerous functions that would aid a radiologist in achieving his/her ultimate result, which is to locate malignant or cancerous regions on an image. The following are some of the features the '*D-Viewer*' is able to perform:

1. Rotate +90 degrees- Rotates image in the clockwise direction
2. Rotate -90 degrees- Rotates image in the anti-clockwise direction
3. Vertical Flip- Flips the image over 180 degrees vertically
4. Horizontal Flip- Flips the image over 180 degrees horizontally
5. Resize- Toggle between big and small sized images
6. Filter Inversion- Alternates the color coding to its opposite value on a pixel scale of 0-255, where black is 0 and white is 255
7. Grayscale- Makes the image gray if it is not already
8. Contrast- Adjusts the contrast
9. Brightness- Determines how bright or dark the image is
8. Sharpen- Makes the image have a finer look
10. Color- Adds the colors green blue of red to the image
11. Gamma- Adds blue, red or green color to the some of the image
12. Zoom- Enlarge the and view of the image by using mouse to draw a rectangle around a region which is then blown up to fill the page
13. Hotkey- Return all manipulated images to their original orientation
14. Undo- Goes back to the last action

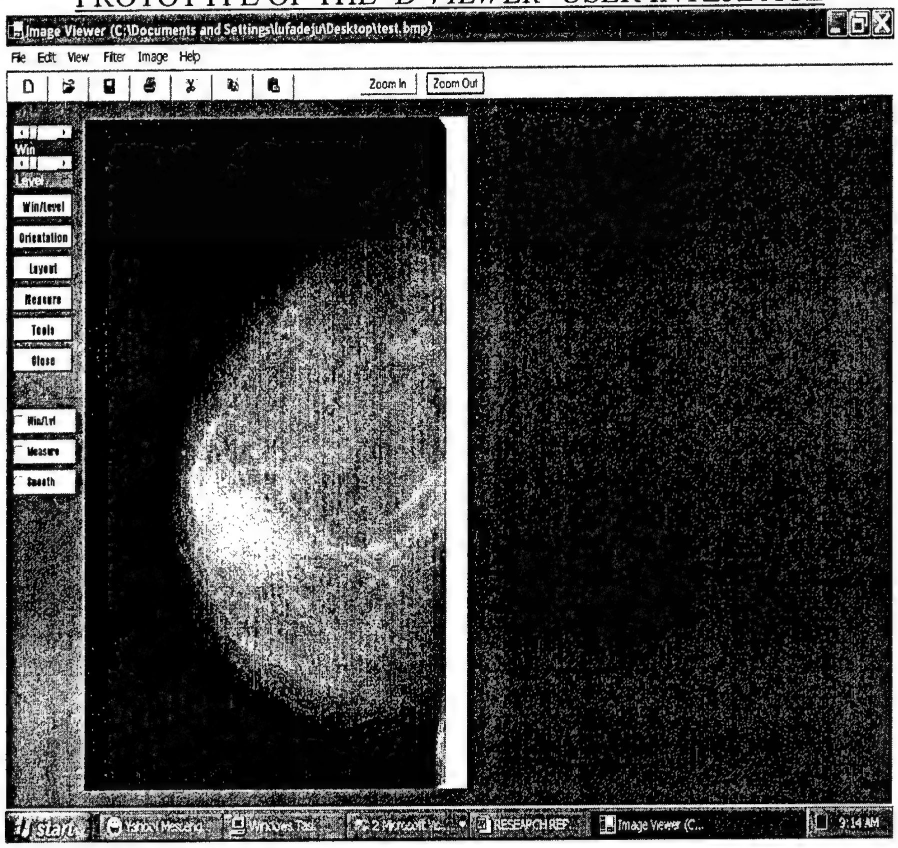
With all these functions, many manipulations can be made to any image including printing for easy access.

Some Other Functions (to be implemented)

The '*D-Viewer*' will eventually be able to view DICOM format images. The contrast and brightness function is an important tool for the radiologist. It gives the radiologist the right

amount of light or dark to detect the patterns and shapes that they look for. A better tool that would be able to make minute adjustments to the contrast and brightness of an image with the aid of a scroll bar is in the making. This tool would make it possible for a radiologist to get the right amount of dark, light or sharpness to achieve his or her goal in detecting cancer.

PROTOTYPE OF THE '*D-VIEWER*' USER INTERFACE



CONCLUSION

The *'D-Viewer'* has been able to cater for the important functions that this imaging software will eventually possess. There are many hospitals nationwide that do not have the appropriate techniques of helping cancer patients. The use of C-Sharp(C#) programming language, which is the newest language presently, used in computing is welcome development. Majority of the medical imaging software in the market today make use of C++, Java or MAT Lab. When more adjustments and modifications are made to meet the present needs in an imaging software, the application would be designated user friendly.

In addition to work on the mammogram digitization and display functions, we have also begun working on DICOM image handling and database for archival of mammograms for future image analysis. Appendix 1 demonstrates the database form. Appendix 2 shows our work on the DICOM image handling.

2.5. Training and Research Activities for the Next Funding Year

a. Development of a mammography database workstation for research and clinical viewing.
b. Digitization of normal mammograms and mammograms containing benign lesions for constructing the mammography database featuring African-American women breast images.

c. Functional development for the use of mammogram database: This project is led by Dr. Chouikha. Since Fall 2003, we have expanded our team to include collaboration with the Center for Applied High Performance Computing, the University of Maryland and QuaTeams, Inc. High-resolution mammograms and advanced algorithms must be accessible for them to be useful. To that end we have designed, and are in the process of implementing, a new end-to-end system that leverages our existing database and research technologies along with advances in technologies from high performance computing, and Grid or Cyber-infrastructure. The purpose is to make the cases in the database and our technologies accessible to researchers and students over the network via an intuitive web-accessible locate data and services that may be distributed over "the grid" and span organizational boundaries. The prototype is designed around proven cyber-infrastructure technologies such as the Globus Grid toolkit and the San Diego Supercomputing Center's Storage Resource Broker (SRB). The initial version will include an interactive client that will provide the ability to sign and annotate mammograms and to request and receive "consults" from radiologists, researchers, instructors, or even expert systems and to find additional cases. Additional functionality is planned to include security certificates, content-based retrieval, and the ability to visualize pathology slides.
d. Medical imaging course

The course was established in the spring semester of 2004 for the graduate students at Howard University (ECE-688). The objective of this course is to introduce practical technologies of medical imaging and their applications. Students from other local universities have also shown interests in this course and are planning to register for it in the upcoming spring 2005 semester. A simplified syllabus of the course is as follows.

Part I: Signals and digital images

Week 1: Overview of course, signal processing basics
Week 2: Fourier transform, signal sampling (HW1)
Week 3: Digital images, image quality, image operations (HW2)
Week 4: Image filters and image enhancement (HW3)

Part II: Brief introduction to medical imaging

Week 5: Medical imaging modalities: X-rays imaging, image quality, devices, clinical application, future development
Week 6: CT imaging (HW4)
Week 7: MRI imaging
Week 8: Ultrasound imaging
Week 9: Nuclear medicine imaging (HW5)
Week 10: Summary of medical imaging (midterm exam)
Week 11: Spring break, no class

Part III: Medical image processing and analysis

Week 12: Medical image segmentation (HW6)
Week 13: Medical image registration (HW7)
Week 14: Deformable modeling (Project 1)
Week 15: Medical applications: image-guided interventions
Week 16: Research oriented seminar and discussion (Project2)
Week 17: Report and presentation by students
Final exam

Textbook

P. Suetens, Fundamentals of Medical Imaging, Cambridge University Press, Cambridge, 2002.

Further readings

R. Gonzalez and R. Woods, Digital Image Processing, Addison-Wesley Publishing Company, Reading, Massachusetts, 1992.
E. Brigham, The Fast Fourier Transform and its Applications, Prentice-Hill International, Englewood Cliffs, New Jersey, 1st Ed., 1988.
S. Mitra, Digital Signal Processing – A Computer Based Approach, 2nd Ed., McGrew-Hill, New York, 2001.

e. Lecture series:
   (1) Image processing
   (2) How to read mammograms
   (3) Normal and abnormal image patterns and texture features on mammograms
   (4) Paper views:
      (a) Computer-Aided Detection of microcalcifications and masses on mammogram
      (b) Computer-Aided Diagnosis for classification of benign and malignant masses in breast MRI
f. Potential Project Activities
   (1) Proposals development for the Bio-medical engineering training program at Howard.
   (2) Network study for high-speed communication.

3. Major Accomplishments

- Provided 6 lecture series in breast imaging and cancer biology (all in graduate level), and 1 grantsmanship workshop for the faculty and students in EE Department, Howard University.
- Mona finished her M.S. in Electrical Engineering. Her work was supported in part by this program under Drs. Chouikha, Lo, and Zeng's supervision. Her thesis title is "Using Gabor Filters Bank on Mammograms: The First Stage of The AM-FM Modeling Technique." Based on her thesis, she planned to submit her work for a potential Journal paper publication.
- Six students received IRB training, passed NIH Human Subject Examination, and received their certificates. Ten students received the training in breast imaging and working on specific training/research topics such as: Advanced Imaging Enhancement Technique for extracting breast cancer features, Display functions, Mammogram database, DICOM, networking, and database design and functions.
- Under Drs. Jendoubi and Wang's leadership, we have digitized 260 mammographic cases (~2000 images). Each image takes 4,000x5, 000x2bytes (i.e., 40Mbytes). This project is intended to develop a mammography database featuring Africa-American women.
- Published a number of papers (see Section 4 below)

4. Reportable Outcomes

1. O'tega A. Ejofodomi, Shani Ross, Ahmed Jendoubi, Jim Humphries, Mohamed Chouikha, Ben Lo, Paul Wang, Jianchao Zeng. "African-American Breast Cancer Research Program", Howard University 2004 Graduate Research Symposium and Honors Day: Enhancing the Research Agenda, Armour J. Blackburn University Center, April 13, 2004.
2. Shani Ross, O.tega Ejofodomi, Ahmed Jendoubi, Mohamed Chouikha, Ben Lo, Paul Wang, and Jianchao Zeng "A Mammography Database and View System for the African American Patients", Applied Imagery Pattern Recognition (AIPR) Workshop, (Dedicated to facilitating

the interchange between government, industry, and academia.) 33rd AIPR Workshop: Emerging Technologies and Applications for Imagery Pattern Recognition (13-15 October 2004), Cosmos Club, Washington, DC.

3. "Using Gabor Filters Bank On Mammograms: The First Stage Of The Am-Fm Modeling Technique", Mona Y. Elshinawy Master Thesis, Advisor: Mohamed F. Chouikha, Ph.D., August 2004.
4. Kinnard L., Lo S-C.B., Makariou E., Osicka T., Wang P., Chouikha M.F., and Freedman M.T., "Steepest change of likelihood function for delineation of mammographic masses: A validation study", Med. Phy., Vol. 31(10), 2004, p.2796-2810. (This paper has also been selected and included in October 2004 issue of Virtual Journal of Biological Physics Research. Only two papers in Medical Physics are selected this time.)
5. M.Y. Elshinawy, J. Zeng, B. Lo, and M.F. Chouikha, "Breast cancer detection in Mammogram with AM-FM modeling and Gabor filtering", Proceedings of the IEEE International Conference on Signal Processing, Beijing, August 2004.
6. M.Y. Elshinawy and M.F. Chouikha, "Using AM-FM Modeling Techniques in Mammograms", Proceedings of the IEEE Midwest International Conference on Circuits and Systems, Cairo, Egypt, December 2003.

Appendix 1: Images information in a tabular form

Sample top of tables used to hold information about images in our database

			Table 1 Cumulative		
	Code #	Patient Name	Series #	Dicom Size/CD	Bitmap Size/CD
1	172	MP828EA633	1	540	67.5
			2	420	52.5
			3,4	300	37.5
			Sub-totals	**1260**	**157.5**
		Pairs of CDs	**3**		

TABLE 2 Cumulative (JLM) : Updated.

	Code #	Patient Name	Series	Exam Date	# of Images In Series	Scanned Date	Doctor's Notes	Types Of Images	Red Marks
1	3	AJ337DU655	1	6/2/2003	5	7/7/2004	N HR	LMLO, RMLO, LCC, RCC, LCC2	N
2	3	AJ337DU655	2	11/8/2002	5	7/7/2004	N HR	LMLO, RMLO, LCC, RCC, LML	N
3	3	AJ337DU655	3	9/29/2000	5	7/7/2004	N HR	LMLO, RMLO, LCC, RCC, LML	N
4	3	AJ337DU655	4	11/29/2001	5	7/7/2004	N HR	LMLO, LCC, RCC, LML, LMLO2	N
5	3	AJ337DU655	5	10/15/1999	5	7/7/2004	Y HR	LMLO, RMLO, LCC, RCC, LML	N
6	3	AJ337DU655	6	4/22/1998	5	7/8/2004	Y HR	LMLO, RMLO, LCC, RCC, LML	N
7	3	AJ337DU655	7	10/15/1998	5	7/8/2004	Y HR	LMLO, RMLO, LCC, RCC, LML	N
8	*3*	*AJ337DU655*	*8*	*9/12/1997*	*4*	*7/8/2004*	*Y HR*	*LMLO, RMLO, LCC, RCC*	*N*
9	3	AJ337DU655	9	1/8/1997	4	7/8/2004	Y HR	RMLO, LCC, RCC, LML,	Y
				Tot. images	43				

Appendix 2: DICOM Images Format

Abstract
The DICOM format is used for the transfer and storage of medical images. A DICOM file contains the header and the image data. The header contains some preamble information such as the offset bytes followed by other extra information, written in the format group: element. The extra information includes the transfer syntax UID, sample per pixel, and photometric interpretation. A program in C# may be written to read and display the DICOM file.

I. Introduction
A. Objective: To read and display DICOM image(s).

B. Background Information:

DICOM is an acronym that stands for 'Digital Imaging and Communication in Medicine'. The DICOM effort has been receiving support from organizations such as *American College of Radiology (ACR), Mallinckrodt Institute of Radiology (MIR), National Electrical Manufacturers Association (NEMA), Radiological Society of Northern America (RSNA).* With the help of digital

imaging resources introduced in the 70's, ACR and NEMA formed a joined committee in 1983. Purpose: to create a standard method to transmit medical images and their associates. In 1985, the committee published ACR-NIMA standards publication No. 300-1985. Version 2.0 was introduced in 1988 and five years later, version 3.0 followed. Now, the later version had delivered its initial promise: "interoperability" (working in multi-vender environment) in addition to transfer of data. This transfer may be visualized as in the diagram below:

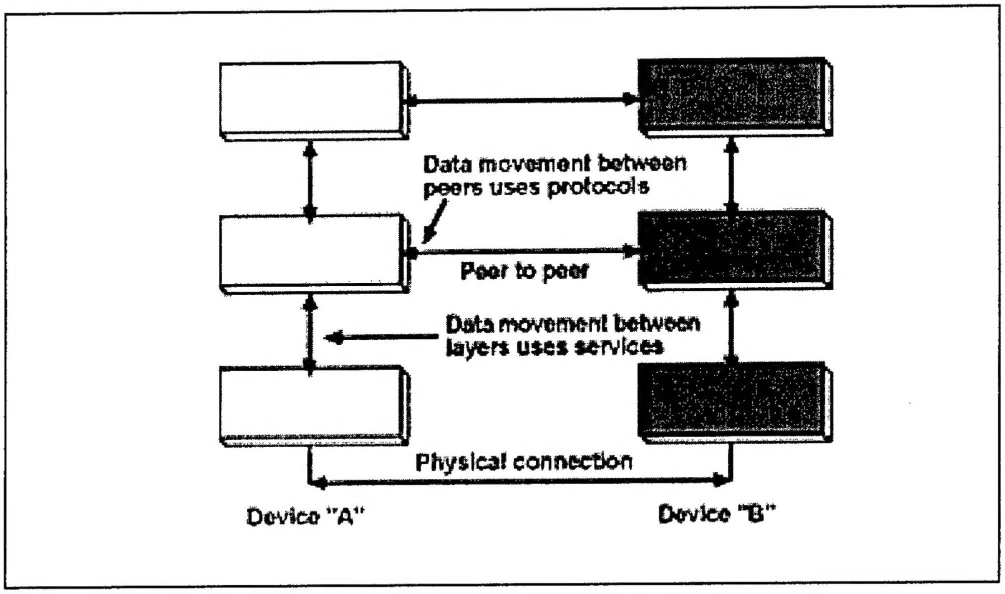


Figure A-1: Diagram shows two simplified communication protocol stacks of three layers each. Vertical communication (within a stack) uses services, whereas horizontal communication (stack to stack) uses protocols. Stack-to-stack communication is physical only at the lowest layer. Peer-to-peer communication (i.e., communication between corresponding layers in different stacks) occurs when information is moved down one stack, over the physical connection, and up to the corresponding layer in the other stack. Courtesy of RSNA.

C. The DICOM Format

The DICOM Standard/Format

The DICOM format is used for transfer and storage of medical images.

DICOM Single File Format

It contains: a) **the header**, which has the patient's name, type of scan, image dimension and so forth and b) **image data**.

The DICOM format is unlike the analyze format: the former has both the header and the image stored together and it is not compressed/encapsulated. From the figure below, the DICOM header takes 794 bytes. The image data takes 19838.

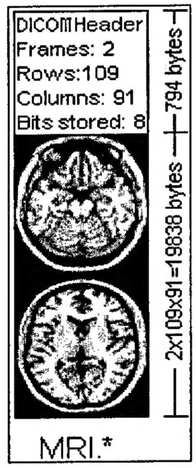


Figure A-2: *Sample DICOM image*

First 128 bytes: unused by DICOM format
Followed by the characters 'D','I','C','M'
This preamble is followed by extra information e.g.:

0002,0000,File Meta Elements Group Len: 132
0002,0001,File Meta Info Version: 256
0002,0010,Transfer Syntax UID: 1.2.840.10008.1.2.1.
0008,0000,Identifying Group Length: 152
0008,0060,Modality: MR
0008,0070,Manufacturer: MRIcro
0018,0000,Acquisition Group Length: 28
0018,0050,Slice Thickness: 2.00
0018,1020,Software Version: 46\64\37
0028,0000,Image Presentation Group Length: 148
0028,0002,Samples Per Pixel: 1
0028,0004,Photometric Interpretation: MONOCHROME2.
0028,0008,Number of Frames: 2
0028,0010,Rows: 109
0028,0011,Columns: 91
0028,0030,Pixel Spacing: 2.00\2.00
0028,0100,Bits Allocated: 8
0028,0101,Bits Stored: 8
0028,0102,High Bit: 7
0028,0103,Pixel Representation: 0
0028,1052,Rescale Intercept: 0.00
0028,1053,Rescale Slope: 0.00392157
7FE0,0000,Pixel Data Group Length: 19850
7FE0,0010,Pixel Data: 19838

Figure A-3: *Header and File information*

Typically, the first 128 bytes are offset. They usually consist of zeros. Then, the letters D T, C M follows. The information that follows is in hex and basically consists of group: element. Depending on the image type, e.g. MR, the element carries length, version or transfer syntax information. All these are requirement for DICOM format. However, viewers such as MRIcro, ezDICOM do not check on this information, but rather just extracts the image size information. One other thing, unlike DICOM, the NEMA format has no data offset buffer, no lead characters D, T, C, M, and does not describe 3-D images.

Of importance is the Transfer Syntax Unique Identification. Its purpose is to check for compression, if any. It also reports byte order for raw data- different computers store integer values differently. There are two orderings: little and the big endian as illustrated below.

Transfer Syntax UID	Definition
1.2.840.10008.1.2	Raw data, Implicit VR, Little Endian
1.2.840.10008.1.2.**x**	Raw data, Explicit VR **x** = 1: Little Endian **x** = 2: Big Endian

Figure A-4: Little Endian and Big Endian

Other specifications include: sample per pixel, photometric interpretation, and bits allocated. The photometric identification for DICOM is continuous monochrome (pixels in gray scale). For MONOCROME1, low means bright and high, dim. For MONOCROME2, low means dark and high, bright. Further still, in case we are dealing with ultrasound modality, color is included described by different photometric interpretations e.g. Palette, RGB, YBR, etc.

II. CODING / APPROACH

The next step was to start working on the program in C# to read and display DICOM image(s). The overview of the program is shown below:

Input: File with DICOM image(s).
Process: Read the DICOM file.
Output: Display DICOM header and image(s).

This was followed by the algorithm/pseudo-code as shown below:

Pseudo-code

1. Declare C# namespaces.
2. Read and display header information,
   a. Declare stream for reading data, bytes from file.
   b. Declare index of current records to be displayed.
3. Create dialogue box to enable the user to open a file.
4. Get file name from user.
5. Show error if user specified an invalid file.
6. Create file stream to gain access to the file.
7. Read bytes from the file.
8. Store file's data in an array.
9. Position pointer to the next record in file.
10. Read data from record.
11. Display data.
12. Display/Draw DICOM image(s).

III. CONCLUSION

We looked at a brief history of the DICOM, considered the DICOM format, touched on some open sources and software development kits, and finally came up with a tentative pseudo-code for a program that would read/display DICOM file: the header and the image. The next task is to translate the pseudo-code into a C# program to read and display DICOM image(s).